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Evaluation of decreasing moisture content of different maize genotypes

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SUMMARY

An experiment was conducted to evaluate the decrease in grain moisture content in three maize hybrids in Debrecen in 2017. Armagnac, Sushi and Loupiac were the examined hybrids in this study. The culture medium and temperature conditions were applied uniformly for all three hybrids. According to the results obtained from the ratio of moisture content of seeds per day, the Armagnac variety in the intensive drying down phase loses more time and moisture content, so it can be concluded that the produced dry matter is more than in the case of other varieties. Armagnac requires more time to achieve yield, while the Sushi and Loupiac hybrids produce less harvest. Regarding the slope of the regression line, the rate of loss of moisture in the grain has been negatively correlated with the amount of "b" in the three examined hybrids. In regression analysis, the coefficient of explanation showed that the effect of day in the Armagnac was 97% in the Loupiac, 95% and in the Sushi 90% of the total dynamic value of moisture motion.

Keywords: *maize, dynamic of water, moisture*

INTRODUCTION

One of the greatest challenges modern agriculture faces is to produce enough food and energy for a world population likely to reach 9.7 billion by 2050. In the past several decades, the yields of major food crops have increased substantially as a result of increased fertilizer use, improved agronomic practices, and genetic improvement. However, the current rate of increase in yield will not keep pace with this increased demand for food and fuel over the next 35 years (Grassini et al. 2013).

Because of the food and economical value of maize (*Zea mays* L.), it is called 'The King of agricultural Products'. The use of maize in human nutrition, feeding of poultry and its industrial application as well as pharmaceuticals has raised its position to such a degree. It is the third most important crop following wheat and rice across the world.

Water is a natural component of maize grain, and has a significant effect on physiological processes, grain quality and profitability. The optimal maize grain water content for combine harvesting is 23–24% but much lower water content is favorable for storage (Bocz 1992).

The change of water content in maize kernel is divided: physiological activities are going on during the development of kernels, whereas, after physiological maturity, a passive drying process is observed (Schmidt and Hallauer 1966). The negative correlation between temperature and water content is significant in the intervals of 75–50% and 50–30%. During the next interval (below 30% water content) weather condition other than temperature alone (relative humidity of the air and the lack of saturation) is important.

Aldrich et al. (1975) claim that after physiological maturity, weather is the most important condition. During the development of kernels, the cytological processes, division, elongation, development of inclusion and rest periods follow each other. All phases require water, but water volume increases initially and declines subsequently.

There is a close correlation between maximum water content and the length of the generative phenophase (Dobos 2003). With good water supply, the maximum of water volume is high and it is favorable from the point of view of a longer and more intense period of accumulating dry matter.

The moisture content of maize kernels is a reliable index of its maturity (Hallauer and Russell 1962). There is a close correlation between the loss of moisture content and kernel filling also plotted against the scale of Growing Degree Dry Day (Kang et al. 1986). Various hybrids and varieties display different levels of stability regarding the influence of effect associated with environmental conditions (Hallauer and Russell 1961). The genotype belonging to a later group of maturity loses moisture at a slower rate but are more exposed to environmental hazards to various extents (Magari et al. 1997). Among these, the role of precipitation or rather GDD+precipitation and GDD+relative to air humidity are decisive in influencing and entering into interaction with the process of water loss in kernels.

The dynamics and duration of water loss depend greatly on climatic factors. Temperature is the most important among them (Bloc and Gouet 1974). Kang et al. (1986) found negative correlation between the mass of kernels and moisture content of the ear (-0.84), however, after full physiological maturation, the role of the kernel mass could be ignored (r=0.04).

Until physiological maturity, active physiological processes prevail. Kang et al. (1986) showed by means of path-analysis a positive interaction between kernel filling and speed of decline in water content percentage, which means that if the speed of kernel filling increases, water loss ensues at higher rate (% loss per day). The rate of water loss depends also on the type of the kernel (Derieux 1975, Derieux and

Bonbomme 1982), the thick layer of the pericarp (Purdy and Crane 1967) and on the quality of the husk leaves (Crane et al. 1959). Neményi (1983) explored the relationship between water loss with water-losing inclination determined by some hybrid genotypes and the structure and chemical composition of the pericarp. Helm and Zuber (1969) also emphasized the decisive role of the pericarp in the loss of moisture content.

It can be concluded that the optimal level of most cultivation technology measures (plant density, fertilization) does not only increase yield, but also decreases the grain moisture content (Kising 1962, Nagy and Zeke 1981). In maize, satisfactory nutrient supplies do not only increase yield, but also improve the water utilization of the plants (Kovács 1982, Nagy 1996, 1998; Németh and Búzás 1991). Irrigation significantly increased the grain moisture content of many hybrids, especially in the case of low nutrient supplies (Nagy and Zeke 1982).

The knowledge of plant constraints limiting yield potential during the grain filling period is necessary to develop breeding and management strategies aimed at increasing harvestable yields. Currently, the assessment of different source-sink ratios during grain filling has shown that wheat (*Triticum aestivum* L.) is mainly sink-limited (Slafer and Savin 1994, Borrás et al. 2004, Zhang et al. 2010); however, Sandaña et al. (2009) working in a high-yield environment, found that wheat is more affected by the source shortage than generally assumed. The physiological bases accounting for the responses reported by Sandaña et al. (2009) are especially important in southern Chile, taking into account that crop production systems are based on temperate cereals, which are favored by high grain weight potential. Thus, a better understanding of the causes behind the higher-than-expected sensitivity of wheat-to-source reduction could improve the knowledge of physiological traits controlling grain weight of wheat in favorable environments.

Given that grain water content has been found to be a key trait in determining wheat grain weight (Egli 1990, Saini and Westgate 2000, Pepler et al. 2006, Hasan et al. 2011), and considering the close balance between water and DM in growing grains (Schnyder and Baum 1992, Calderini et al. 2000, Saini and Westgate 2000, Pepler et al. 2006), studying grain water content in response to the source-sink reduction during grain filling could provide useful information on grain growth and its responsiveness to source constraints of cereals (Borrás et al. 2003, Borrás and Westgate 2006).

MATERIAL AND METHODS

Samples were taken in location in Debrecen. The Experimental Station is situated on the Hajdúság Loess Ridge, and the soil is a lowland chernozem with lime deposits and a deep humus layer, formed on loess. It has medium hard loam texture. The soil type is solonetz, strongly calcareous, meadow chernozem, with loam or sandy loam texture.

The daily precipitation sum was determined by local measurements, while the daily radiation and temperature data were provided by the Meteorological Observatory Debrecen the National Meteorological Service in Budapest. Among the agrometeorological parameters, an analysis was made of the precipitation during the growing season, effective heat sums during the vegetative and generative phase, and the water supplies. The daily heat sums were determined using the algorithm proposed.

In 2017 the total rainfall from May until October was 314 mm in Debrecen, which was 236 mm for winter period before sowing.

In the course of sampling the weight of 100 grains from the middle section of 4 ears was measured in 4 replications. Dry matter content was determined after drying to constant weight in a drying cabinet at 60 °C.

Thus the computation of the sum of temperature should be performed according to Gilmore and Rogers (1958), Arnold (1959, 1960), moreover, to Cross and Zuber (1972) by the following formula:

$$\sum_{1}^{n} T_a = \left(\frac{Max - Min}{2} \right) - T_B \quad {}^{o}C$$

where: ΣT_a is the sum of the active temperatures throughout the growing season, the expression of the fraction corresponds to the mean value of daily mean temperature, and the T_B is the basic temperature.

The value of the degree-day is obtained by the formula:

$$\text{degree - day} = \left[\left(\frac{Max - Min}{2} \right) - T_B \right] \quad {}^{o}C\ day^{-1}$$

The most accepted one is proposed by Gilmore and Rogers (1958) based on a regression analysis, which postulates that the growth is linear during the first phase of development – being demonstrated relatively well – and the horizontal axis of the graph is the temperature. The vertical axis is assigned to the volume or height of the plants. The intersection of (linear) growth with the horizontal axis (x) indicates the base temperature.

Another method using a more reliable database is proposed by Szász and Nagy (2006). The distribution of probability of growth over temperature gives an asymmetric ß-distribution, hence the ß-model of the distribution.

As far as the lower value of the daily variation of temperature is above the base temperature, in order to establish the active values of temperature, we must know the temperature below which the values ought to be omitted when making the sum. This value is generally found by statistical methods from the database of climatological observations applying a cubic equation, which describes the variation of the latter value until the end of the flowering period (Tollenaar et al. 1979, Ritchie et al. 1994).

In Hungary, 10–12 °C daily variation is nearly constant at least from the point of view of the phenological phases of maize; according to our studies this is the case also in other regions. Detailed investigations were performed in Canada, USA, and in Western and Eastern Europe. Extended climatological analyses revealed that in the region of 40–46° latitude of North America the daily variation of the temperature during the vegetative phase of vegetative development of maize (May–July) was around 12 °C, and the difference between the regions referred to was some tenth of degrees only, whereas in Western Europe – e.g. England, where maize is grown – daily variation is 6.5 °C. In Western Europe the variation is 10.0–11.0 °C, in Southern Europe 6.0–8.0 °C, respectively. After all, the question of base temperature ought to be solved by different approaches in those regions.

RESULTS

Water is only natural in maize grain, and it has a great impact on the physiognomic handling, grain quality and economic yield. At most of the time, water harvesting is appropriate for about 23% to 24% of the seed. If the water content is less than 23%, it is suitable for storage. As we know, after the flowering process, the transfer of material to the grain filling in the ear goes to add dry matter composition and is accompanied by changes in the moisture content of the seeds. The dynamics of water movement in maize grain is carried out in 3 stages.

The first stage is the maximum phase of water, which is for the Armagnac from 103 to 112 days, for Loupiac from days 103 to 106, and for Sushi from 103 to 109 days. At this stage, maize grains had been the highest moisture content.

The second phase is the intensive drying phase (phase of intensive drying down), which is for the Armagnac from 112 to 130 days, for Loupiac from 106 to 123 days and for Sushi from 109 to 130 days.

As we observe, the Armagnac variety loses more moisture content so it can be concluded that it produces more dry matter than Loupiac and Sushi.

The third stage is the physical drying down phase (phase of physical drying down), which is for the Armagnac from 130 to 155, for Loupiac from 123 to 155, and for Sushi from 130 to 155 days. At this point, maize is considered to be harvest and can be harvested for storage (*Figure 1–3*).

The dynamics of water movement in maize grain of Armagnac, Lopiac, and Sushi in the Debrecen area showed that the best time for harvest is 130 days for Armagnac, 123 days for Loupiac 130 days for Sushi. According to the Armagnac variety, which requires more time to achieve yield, the Sushi and Loupiac hybrids require less time to produce physiological yield.

Figure 1: **Phase of drying down for Armagnac (2017)**

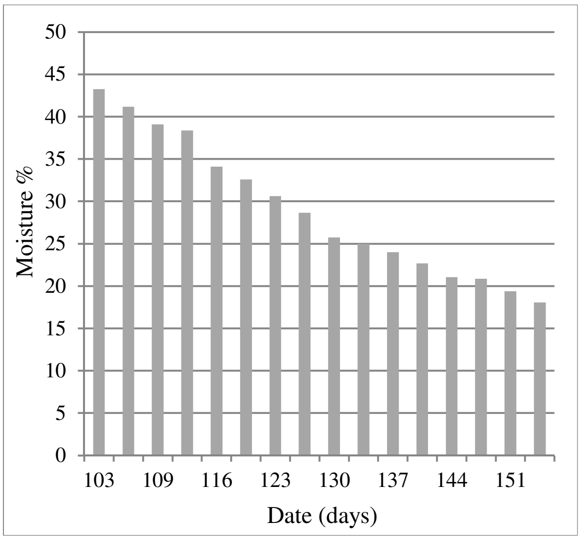
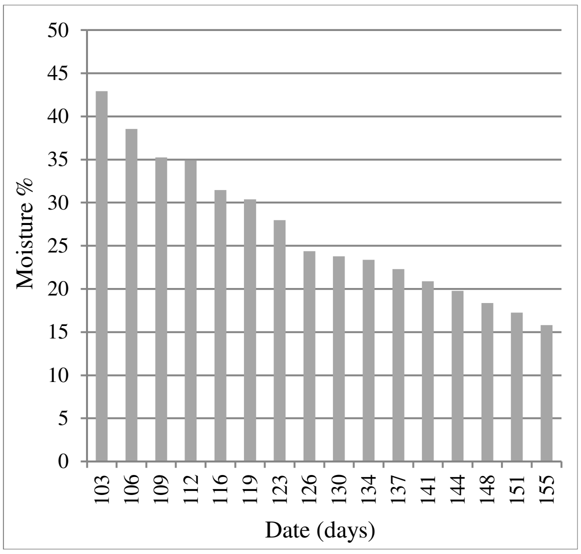
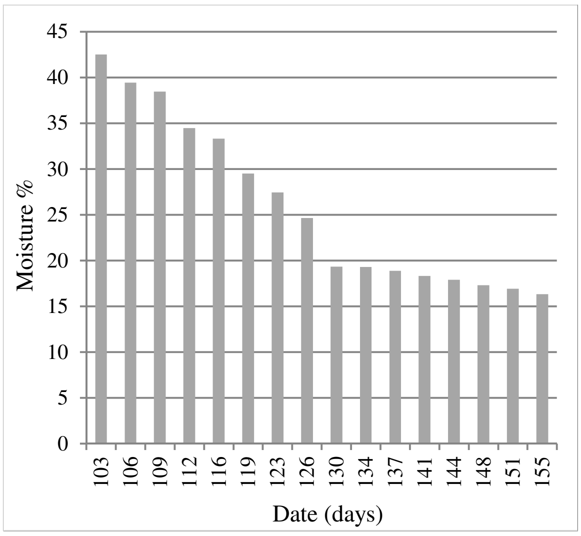


Figure 2: **Phase of drying down for Loupiac (2017)**



The aim of the regression line slope is to predict the behavior of the dependent variable with the knowledge of the values and characteristics of the independent variables using the regression line equation. The next step was to determine how the location affected the dynamics of drying in the Armagnac, Loupiac, and Sushi varieties. Drying rates were similar in Armagnac and Loupiac hybrids. The rate of moisture in the seed has been negative and decreased due to the amount of “b” in the three hybrids.

Figure 3: **Phase of drying down for Sushi (2017)**



In regression analysis, the coefficient of explanation showed that the effect of day in the Armagnac was 97% in the Loupiac, 95% and in the Sushi, 90% of the total amount of dynamic motion of water was explained. Of course, the determination coefficient (R^2) is useful in determining how well a data regression equation fit. But, as we have seen, the determination coefficient alone is not sufficient to verify the model's accuracy, and in addition to the determination coefficient (R^2), the normality of the data or the residuals, the variance of the variables at different levels, the independence of the data relative to time and non-oblique Observations are evaluated for the correctness of the fitted model (*Table 1*).

Table 1

Drying down dynamics of maize hybrids with different genotype in the intensive phase (Debrecen, 2017)

Genotype	FAO no.	Regression equation	R^2
Armangnac	490	-0.4857x+91.391	0.9711
Loupiac	380	-0.474x+87.561	0.9534
Sushi	340	-0.5248x+93.252	0.9099

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